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Application and Research of Fuzzy Control Simulation in Twin Screw Extruder

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Abstract

The quality of rubber machinery equipment does not only depend on its machinofacture, but also depend on its automation control level. Twin screw extruder is the important auxiliary engine of internal mixer. Due to the intermittent working of internal mixer, the speed control of twin screw extruder has nonlinear and time invariance problems. According to twin screw extruder system's characteristics, this paper proposed adopting fuzzy control to improve its system with the view of advancing twin screw extruder's production efficiency and service life. It also built twin screw extruder's traditional screw speed control system and the system adopted fuzzy control. It can be seen from the comparison that the modified twin screw extruder is more advantageous.

Keywords: robotization; system control; algorithms; MATLAB/Simulink; speed regulating system;

1. Introduction

As the auxiliary engine under internal mixer, twin screw extruder (TSE) is one of the key processing equipments in mixing line. The simulation and experiment for TSE control system has great value in reducing the development cost and improving product competitiveness [2].

The major function of TSE is prompt pushing the material mixed by internal mixer to rollers by two screws synchronized relative circumrotating, and flattening them to slice. If the rubber compounding can't be squeezed out in time, the inner rubber compounding will be scorching [3].

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The intermittent working of internal mixer and the high elasticity of rubber make the TSE control system exists nonlinear, time-vary and other complex problems. Thus there are many disadvantages in traditional control system as a result.

Fuzzy Control mainly solves some nonlinear, time-varying and complicated system's control problem which can't be solved by traditional method [4].

This paper uses the MATLAB/Simulink to simulate the speed control of TSE, and uses Fuzzy toolbox to establish fuzzy controller, then apply it to the TSE speed control model. Finally, it compares the control effect of these two models.

2. The Introduction of Speed Control System of Twin Screw Extruder

Different factory has different speed control system for TSE. This paper discussed one of these systems. TSE speed control system regulates roller/screw motor speed by controlling the motors' current. Considering how much material in the feeding hopper, controller would set roller/screw speed to a predetermined value. Based on these, the screw speed would be regulated according to the motor current.

2.1. Simulation of Direct Current Speed Control System

The research object of this paper is the screw speed control of TSE. The screw adopted separately excited direct current motor. Thus this paper adopted speed and current double closed loop to be the basic model for TSE speed control system [6].

2.2. Simulation of Traditional Speed Control System For Twin Screw Extruder

According to speed characteristic of DC machine [7], this system would judge the load's weight by feedback signal of armature current. Screw speed needs decrease when rubber is too much to make intense pressure to screw; screw speed needs increase when rubber is too little to make the current of screw motor too low. Screw should stop before the rubber in screw run out in order to produce the rubber sheet continuously. This system's rate of increase/decrease in speed was one turn per unit time.

A traditional speed control system model of screw motor can be obtained by the use of Simulink as showed in Fig.1.

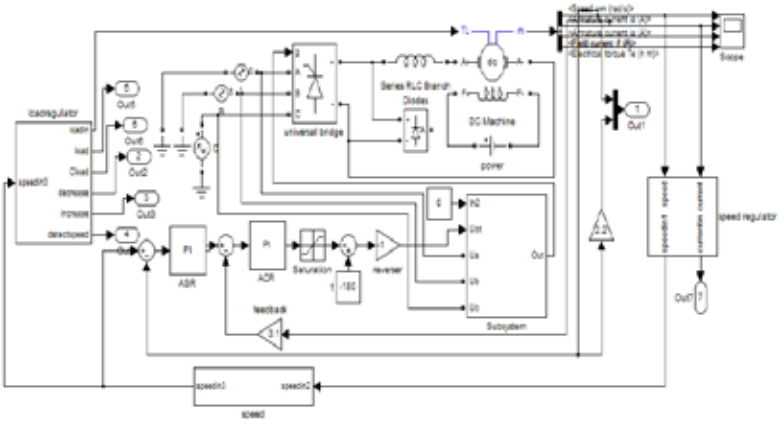

Fig.1 traditional speed control system simulation of Twin Screw Extruder

In this simulation of traditional system: The motor current would suddenly increase by the abruptly increase of load. During this moment, when current larger than reference value motor speed would decrease one turn per unit time by using the feedback segment composed of signal holding module and other modules, and the load and current of motor decreased because a feedback. Contrarily, motor speed increased when current less than reference value, and the load of motor would increase, then the current would increase too. When load returned to the value that made the current back to the reference value, speed would come back to the reference set previously. Load signal is shown in Fig.2:

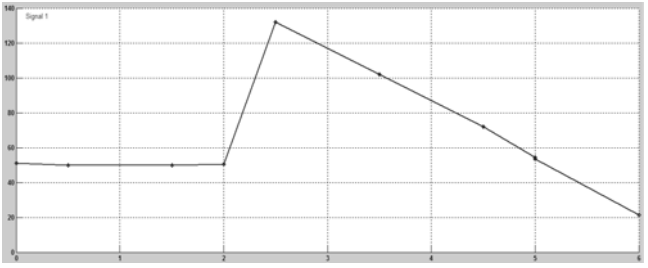

Fig.2 load signal

Speed Simulation result is shown in Fig.3:

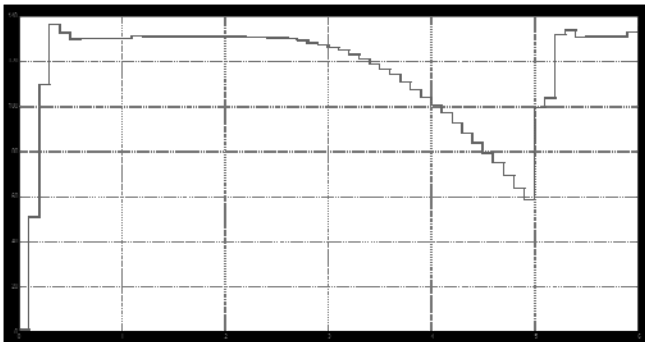

Fig.3 motor speed simulation result

The horizontal axis showed times in second. The vertical axis showed the speed in rad/s. The result showed that: when load was about 50, motor speed would rise from the initial 0 rad/s to 130 rad/s. After 2 second load would increase abruptly, motor speed would begin to decrease. But it was not until 5 second that the load influence eliminated, and the speed accelerated. This was all because of the decreasing speed had slight effect on the decreasing of load Then it can be predicted that, one turn decrease per unit second of speed may not keep up with the exceedingly fast increase of load, and this would make the motor with high loading in long time. This would scorch the rubber before they are extruded. What's more, when load made current fall to reference value, decreasing speed would rise to default immediately. These two situations will all affect motor's service life.

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3. MATLAB Realization of Speed Control System Based On Fuzzy Control

This paper used fuzzy controller with the structure of two inputs and single output [5]. The two inputs were the current error E and the current error rate of change △E. The current error E was the difference between real-time current value and reference. The output was motor speed's control value U.

After completed fuzziness of E and △E, fuzzy system reasoned them by FIS editor. Outputted exact value after these and finally used it to control screw motor current.

This paper used Mamdani in FIS, which meant the outputs' linguistic value was routine fuzzy set. It was confirmed by experiments that, the current input was between 0~90A, its ideal value was 45A, then the basic argumentation of current error E was [-45, 45]. This paper quantized it to [-3, 3], and defined 5 fuzzy linguistic values: PB, PS, ZO, NS, and NB.

The basic argumentation of current error rate of change △E was [-80, 40], this paper quantized it to [-3, 3], and defined 5 fuzzy linguistic values: PB, PS, ZO, NS, and NB. The current error E and the language variable △E all use Gaussian function as membership function.

The state of output U can be divided into 7 grades: PB, PS, ZO, NS, and NB. The membership function of U is Trapezoid function.

3.1. Fuzzy Control Model

This paper built a fuzzy control system model based on elements of fuzzy control as shown in Fig.4:

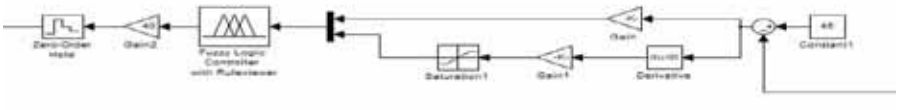

Fig.4. fuzzy control segment of system

3.2. Simulation of Controlling The Adjustable Speed By Fuzzy Control For Twin Screw Extruder

The simulation connected the fuzzy controller to the motor speed regulating system based on the principle of fuzzy control system. The result of simulation was shown in Fig.5:

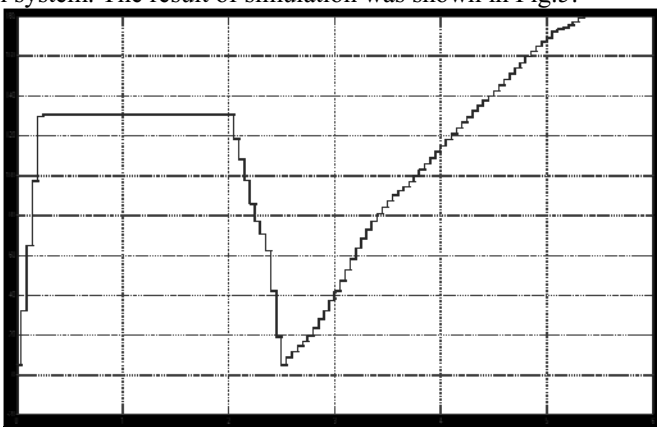

Fig.5 simulation result of speed regulating by fuzzy control

The horizontal axis showed times in second. The vertical axis showed the speed in rad/s. As shown in the pictures, motor's load was about 50 in initial status, and the motor speed raised quickly and smoothly from the original speed 0rad/s to 130rad/s. Motor speed declined in time when load became larger suddenly, and didn't' stop declining to ascend until the current lower than reference. By contrast, this control system can decrease load more quickly, and motor speed will not change too much during normal operation state.

In a word, this system is better than traditional system to some extent.

4 Summarize

This paper built a screw DC motor speed regulating system by MATLAB R2007b, and simulated traditional speed control system of twin screw extruder based on this simulation. Then it built a speed control system model which used fuzzy control to compare with traditional system. The simulation showed that, the application of fuzzy control in motor speed regulating is theoretically possible. The subsequent work only has to realize the fuzzy control in its control system by PLC. To do the improvement research of TSE plays an important part to the improvement of compounded stock and production efficiency. It did not only provide the theoretical guideline for the fuzzy control applied in twin screw extruder, but also gave reference for the other speed control and temperature control in industrial control.

Acknowledgements

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